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SE&I SYSTEM TESTABILITY

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THE KEY TO SPACE SYSTEM FDIR AND VERIFICATION TESTING

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INTRODUCTION

Space Transportation systems of the future will be required to operate in an autonomous fashion for several years at a time in very remote environments (low earth orbit, on the moon, and other planets). This fact coupled with the fact that maintenance man hours will be severely limited and ground based personnel implementation of test and diagnostics will be too costly for even the most optimistic budget scenario leads us to conclude that on orbit test, checkout and diagnostics must be highly automated and implemented with the same degree of emphasis and importance as functional capabilities.

At the recent space transportation avionics technology symposium, it was pointed out that over 50% of the space shuttle budget is required for operations. All attendees agreed that a primary contributor to this fact was the lack of automation in the test and checkout process and the FDIR system. Future systems must incorporate automated systems, which are well within our present state of the art capability. The Department of Defense has made major strides to eliminate operational costs via the implementation of self-diagnosing systems on all major new aircraft and weapon systems.

The key to implementing self-diagnosing design is a systems engineering task focused on design for testability concurrent with design for functionality.

The design for testability process described herein is the product of several years of DOD study and experience. Its application to the space station has begun on Work Package II under NASA and McDonnell direction. Other work package teams are being briefed by Harris Corporation (with hope) of convincing them to embrace the process.

WHAT IS TESTABILITY

For the purpose of this discussion the term testability is used to describe the systems engineering process by which designers can assure themselves and their reviewers that their designs are "TESTABLE," that is they will support the downstream process of determining their functionality. Due to the complexity and density of present-day state-of-the-art designs, such as pipeline processors and high-speed integrated circuit technology, testability feature design is a critical requirement of the functional design process.

THE OBJECTIVE OF TESTABILITY

In most cases an individual is interested in only one of many uses or reasons for making an item "TESTABLE" or they are involved in only one step in the testability process. However, the needs for testability in a product cover such areas as FDIR, maintainability, safety, design verification, and acceptance testing of the "as-built" product. Each of these uses has special requirements which can be met through providing embedded test points or instrumentation, providing means to open closed loop systems, and using other approaches which increase ones ability to measure the functionality of the product, and to some level of detail, it's component parts. This is usually accomplished with some associated processing software either embedded or in test equipment. The key objectives of the manned space program testability design process are listed in Figure 1.

- Optimize System FDIR
- Optimize System Test and Verification Interfaces
- Minimize Weight and Power of BITE

Figure 1.

THE PROCESS

Figure 2 depicts the flow of system/ORU testability and test procedure development activities which should be integrated into the system/ORU design process.

Maintenance man-hour constraints, astronaut skill level, and other logistics analysis constraints are used to determine on orbit testing requirements. The level of ground participation in operational testing as well as pre-launch test and verification needs are summed up as ground test requirements. With this data the systems engineering process of testability design can begin.

The first step in the process is to allocate testability requirements to BIT vs. on-orbit management systems vs. ground-based work centers. These requirements which involve built in system/ORU interfaces and/or processing for a summary list of testability requirements which must be addressed by system/ORU designers. Items such as fault isolation to one or more ORU's with attendant confidence factor would be a particular element of such a requirements document as would mean time to isolate, etc.

Given these requirements the systems engineering team can concurrently design to the functionality and testability requirements of their system/ORU.

The testability analysis process is one in which the design as defined by a CAE net list or equivalent representation is evaluated manually or computer aided by a system* testability analysis software tool to detect design features which threaten the downstream testing process. Such features as closed loop processes, which have no mechanism built in to break the loop, are typical. So the CAE design is iteratively challenged prior to completing detail design to insure testability. A second step in the process involves the generation of a suitable monitoring and diagnostic strategy for the item being designed. This process as was the case in testability analysis can be accomplished in a manual fashion or computer aided using the system testability analysis model. The product of this task is the detail definition of built in test functions such as test points, signal conditioning, and/or data processing which are required to implement the monitoring/diagnostic process. As the system is being designed and developed a parallel activity is conducted by the diagnostics engineer, which will yield test software for both the embedded (on orbit) and off-line (most likely ground based) fault management system. As in the case of testability analysis, this software generation process can be accomplished using computer based software products which will generate machine code to match detail testing procedures for both embedded diagnostics and off-line ATE diagnostics.

At the present time Harris Corporation and McDonnell Douglas are applying computer aided testability analyses to the systems of Work Package II. Figure 2 depicts the process which is being implemented. Using JSC 31000 guidance, testability requirements are being documented in a station level FDIR specification. These requirements are supplemented with RM+S data to form a complete set of station level data. The first task in this process is to develop a dependency model description of the station level connectivity of the Work Package II systems. The testability analysis process is then used to describe a station level diagnostic strategy. The main task of this diagnostic strategy is to do the processing and control functions which are necessary to resolve conflicts between systems. It is that software

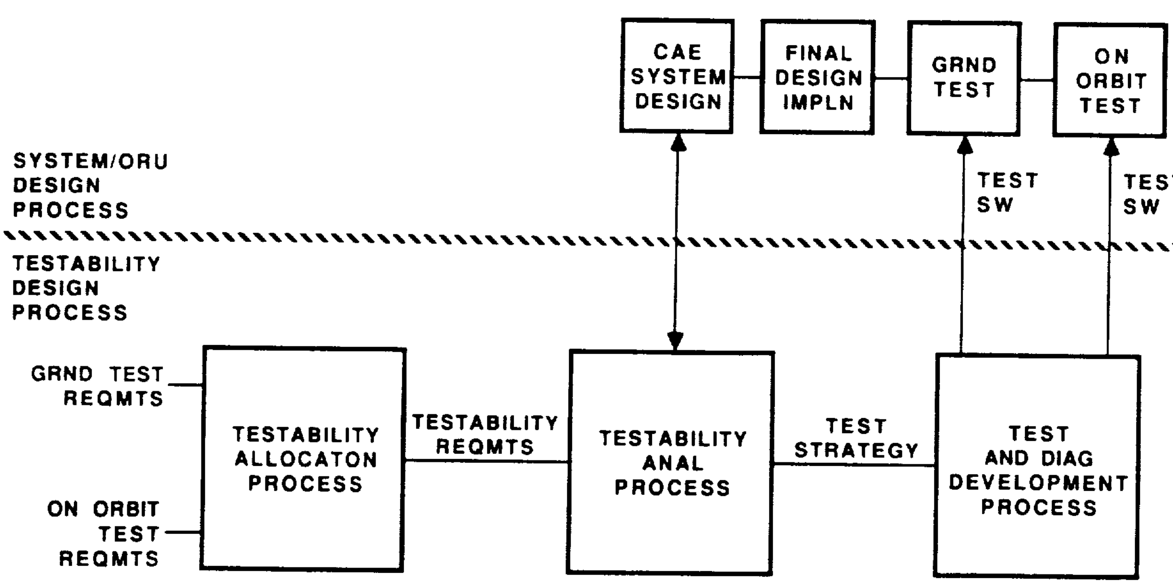

Figure 2. Test and Checkout Development Process

which resolves multiple fault alarms and covers those faults which cannot be handled by the individual systems FDIR software.

Having completed this first step, a specification will be developed which will describe the functions which must be implemented by the OMS system and it will describe for the individual systems design teams (COM + TRACK, GNC, DMS, etc.) the data which they must deliver to OMS to support the station level diagnostics process.

The remainder of Figure 3 shows the activity which will take place within the system level design teams organizations.

The overall impact of this analytically derived top down test strategy development process is an optimization of test point allocation and minimization of data bus traffic, since only data necessary to satisfy the next level of test will be passed from individual built-in test processors. Experience on several large DOD Programs has shown that unless this process is implemented, each system and ORU designer will make a judgment as to what data could be used by the next level diagnostic processor and this leads to computational and data handling explosion.

TESTABILITY TOOLS

Over the past 10 years there have been various pockets of energy within major corporations and small systems engineering houses to develop testability analysis tools. In general all of the tools approach the problem from the perspective of modeling the system/ORU under test using dependency model representation. Once the computer aided design work station has developed this representation, several processor functions are called in to assess testability and interact with the design engineer in a user friendly fashion to help him correct problems noted. Once the system/ORU testability features are included in the design, work begins on the process of selecting optimum search strategies which form the diagnostic (fault tree) approach. Having arrived at this point in the process, an optimum set of test points and test procedures are developed for implementation.

One such testability analysis model has been selected for the Space Station Freedom Work Package II activity. The selected tool is a product of a DOD development contract and as such is available to prime and subcontractor teams. The System Testability Analyzer Tool (STAT) will also be added to the space station Software Support System Environment (SSSE) tool set. Although this tool is being used for the station level work described above by McDonnell/Harris, other subcontractors may be more comfortable with their in-house tool.

The space station testability analysis tool (STAT) is identical to the DOD Weapon System Testability Analyzer (WSTA) tool; this tool is described in detail in Reference I to this paper. Harris Corporation is the developer of this product and may be called for more detailed

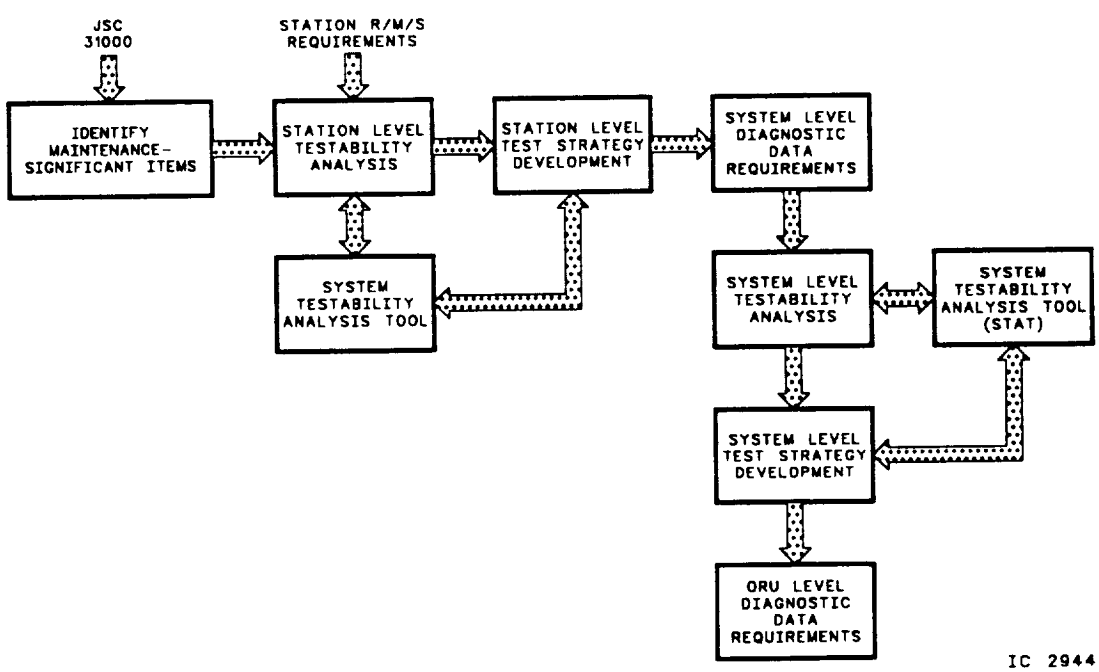

Figure 3. A Top-Down Systems Approach to FD/FI Design

information. The Harris contact is Dr. Bruce Rosenberg and he may be reached at (516) 677-2769. A compatible set of implementation tools are also being developed by the DOD and Harris Corporation which will soon be available to all contractors. The key tool among these is a generic expert diagnostics software package which is designed to be an embedded processor to execute the STAT developed test strategy within a system/ORU or /OMS processor. This tool has data bases which support improvement of testing efficiency over time and a rule based reasoner to accommodate multiple alarms and false alarm discrimination. It is expected that this DOD product will be widely used in both on orbit and ground based testing systems.

IMPLEMENTATION OF TESTABILITY ON SPACE STATION FREEDOM (SSF)

As described above, testability implementation on SSF is a distributed task. The prime contractor MDAC in the case of Work Package II will implement station level testability analysis and test strategy development which will be executed by the OMS. Each of the sub tier contractors (RCA, IBM, Honeywell, etc.) will implement system/ORU testability using software and processors within their systems. Since the SSF STAT will be available to all work package contractors via the SSE tool box, it is expected that they will use it. This tool will be configuration managed by the DOD and Harris Corporation.

TECHNOLOGY ISSUES IN TESTABILITY

Figure 4 lists some of the technology issues being addressed by the SSF contractors and NASA. Although the STAT tool is available today, the system developers are not yet totally aware of it. SSF will be the first real application of testability analysis and development within the space program. It is generally agreed that the process is required to insure maximum operational availability of SSF functions, but this must be communicated across all work packages. To accommodate automatic transfer of CAD data (net lists, etc.) to the STAT tool data base, preprocessors will be required for each CAD system. Two presently exist for Daisy and HP CAD systems.

- TIMELY ACCEPTANCE BY SYSTEM DEVELOPERS
- LACK OF NASA APPLICATION/PROOF OF CONCEPT
- HOW MUCH TESTABILITY IS ENOUGH
- QUANTITATIVE RELATIONSHIP OF TESTABILITY AND AVAILABILITY
- NON-UNIFORMITY OF CAE TO TESTABILITY TOOLS INTERFACES
- TOOL USER FRIENDLINESS

Figure 4. Testability Technology Issues

CONCLUSION

A systematic approach to Space systems test and checkout as well as FDFIR will minimize operational costs and maximize operational efficiency. An effective design for the testability program must be implemented by all contractors to insure meeting this objective. The process is well understood and technology is here to support it.

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